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Novel design and synthesis of a radioiodinated glycolipid analog as an acceptor substrate for *N*-acetylglucosaminyltransferase V

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Guided by the known molecular recognition interactions between *N*-acetylglucosaminyltransferase V (GnT-V) and certain synthetic substrates, we synthesized a radiolabeled double-stranded glycolipid composed of a long-chain alkyl unit and a radioiodinated phenylalkyl unit, [^{125}I]-2-[*N*-(2-hydroxy-3-hexadecyloxy)propyl-15-(4-iodophenyl) pentadecanecarboxamido]ethyl 2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→2)-α-D-mannopyranosyl-(1→6)-β-D-glucopyranoside ([^{125}I]2), as a novel intravital glycolipid mimic substrate of GnT-V. The radioactive iodine (^{125}I) was incorporated via iododestannylation of the phenyltributyltin derivative, 2-[*N*-(2-acetoxy-3-hexadecyloxy)propyl-15-(4-tributylstannylphenyl) pentadecanecarboxamido]ethyl 3,4,6-tri-*O*-acetyl-2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→2)-3,4,6-*O*-acetyl-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-acetyl-β-D-glucopyranoside (26). Subsequent deacetylation at the final step afforded [^{125}I]2.

Keywords: radioiodinated glycolipid analog; *N*-acetylglucosaminyltransferase V (GnT-V); trisaccharide; double-stranded lipid

Introduction

Glycoconjugates on cell surfaces play critical roles in biological events, such as development, carcinogenesis, and malignant transformation. Recent studies revealed a close relationship between the production of unusual sugar chains on cell surfaces and malignant cell transformation; a variety of highly branched oligosaccharides have been identified on tumor cell surfaces. Several studies over the past two decades have demonstrated that *N*-acetylglucosaminyltransferase V (GnT-V) is one of the most relevant glycosyltransferases for tumor invasion and metastasis. Since Cummings and his colleagues reported GnT-V expression in mouse lymphoma cells in 1982,[1] GnT-V has been shown to be highly expressed in a variety of cancer cell lines starting from the early stages of tumorigenesis.[2–8] Some biological studies of GnT-V-deficient mice have directly demonstrated the essential role of the transferase in the growth and metastasis of tumor cells.[9,10]

With the aim of developing an imaging tracer for GnT-V activity, we previously reported the synthesis of the radioiodinated trisaccharide derivative, 2-(4-[^{125}I]iodophenyl)ethyl 2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→2)-α-D-mannopyranosyl-(1→6)-β-D-glucopyranoside ([^{125}I]**1a**, [^{125}I]IPGMG), which has a K_m of 23.7 μM and a V_{max} of 159 pmol/(h·μg) toward GnT-V in vitro (Figure 1).[11] [^{125}I]**1a** was not expected to incorporate into the Golgi apparatus, where GnT-V is excessively expressed, because of a low hydrophobicity; the calculated value of log P (clogP) for [^{125}I]**1a** was −1.69.[†] Increasing the hydrophobicity of **1a** is expected to be important for increasing the molecule's permeation into the Golgi apparatus in the design of reliable and useful substrates. We next sought to synthesize the trisaccharide derivatives [^{125}I]**1b** and [^{125}I]**1c**, which bear longer alkyl chains than the *p*-iodophenylethyl group, for example, the *p*-iodophenyloctyl or *p*-iodophenylpentadecyl groups (Figure 1).[12] [^{125}I]**1b** and [^{125}I]**1c** were expected to display a higher permeability through the cell membranes and into the Golgi

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[†] Calculated logP values were obtained computationally using ACD/Labs v.12.0 (Advanced Chemistry Development, Toronto, Ontario, Canada).

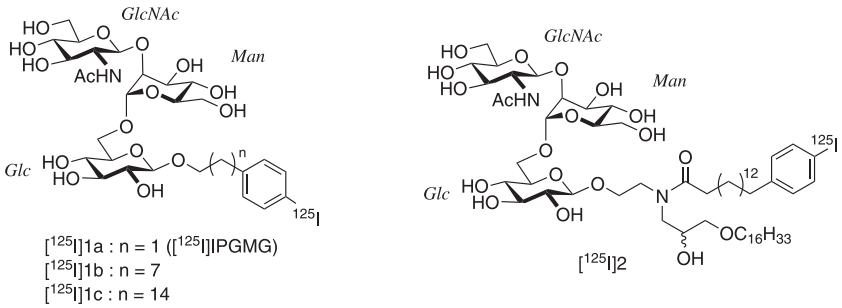


Figure 1. Structures of the ^{125}I-labeled trisaccharide derivatives [^{125}I]**1a–c** and [^{125}I]**2**.

apparatus than [^{125}I]**1a** based on the higher clogP values ([^{125}I]**1b** clogP = 1.14; [^{125}I]**1c** clogP = 4.86).[†] In fact, [^{125}I]**1c** showed better uptake profile in comparison with [^{125}I]**1a** and [^{125}I]**1b** ([^{125}I]**1c** [^{125}I]**1b** > [^{125}I]**1a**).[‡]

Certain intravital glycolipids, such as sphingoglycolipids or glyceroglycolipids, consist of double-strand structures with two long alkyl chains. The structures of these glycolipids could play an important role in their interactions with other glycolipids or cells. Here, we designed an alternative GnT-V-specific radioiodinated glycolipid analog that could be incorporated into the cell. A neoglycolipid aglycon moiety was designed to have a double-strand structure composed of a long alkyl chain and a radioiodinated phenylalkyl unit. We synthesized a novel ^{125}I-labeled glycolipid [^{125}I]**2** via a key intermediate, from which the aglycon moiety could be facilely modified in a few steps just prior to incorporating the radioiodine atom (Figure 1).

Results and discussion

In a retrosynthetic study of [^{125}I]**2**, the phenyl carboxylic acids **3** and **4** were coupled to the trisaccharide derivative **5**, which could be obtained by reductive amination of the primary amine **6** and the aldehyde **7** (Scheme 1). The aldehyde **7**, bearing a trisaccharide composed of *N*-acetyl-D-glucosamine (GlcNAc), D-mannose (Man), and D-glucose (Glc), was synthesized via the thioglycoside glycosylation using odorless benzenethiol as the activating group.[12–15] Successive glycosylation reactions using *p*-dodecylphenyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranoside (**8**)[13,14], *p*-dodecylphenyl 2-*O*-acetyl-3-*O*-benzyl-4,6-*O*-benzylidene-1-thio-α-D-mannopyranoside (**9**)[13,14], and 2-(2-nitrobenzyloxy)ethyl 2,3,4-*O*-benzyl-β-D-glucopyranoside (**10**) afforded **7**. The *o*-nitrobenzyl group was chosen as the protecting group on the aglycon glucoside moiety **10** because it could be selectively cleaved by sunlight photolysis[16,17] after the construction of the trisaccharyl moiety.

First, we synthesized the glucoside **10** as a glycosyl acceptor. The glycosylation of 2-(2-nitrobenzyloxy) ethanol (**11**)[18] with penta-*O*-acetyl-β-D-glucopyranose in the presence of $BF_3{\cdot}Et_2O$ gave the glucoside **12**, which was then deacetylated. The free β-D-glucoside **13** obtained was treated with trityl chloride to afford the 6-*O*-tritylated glucoside **14**. Subsequent treatment of **14** with benzyloxy-2,2,2-trichloroacetimidate in the presence of a catalytic amount of trimethylsilyl trifluoromethanesulfonate afforded the tribenzyl ether **15**. Treatment of **15** with hydrogen chloride in 1,4-dioxane, to cleave the trityl group, gave **10** (Scheme 2).

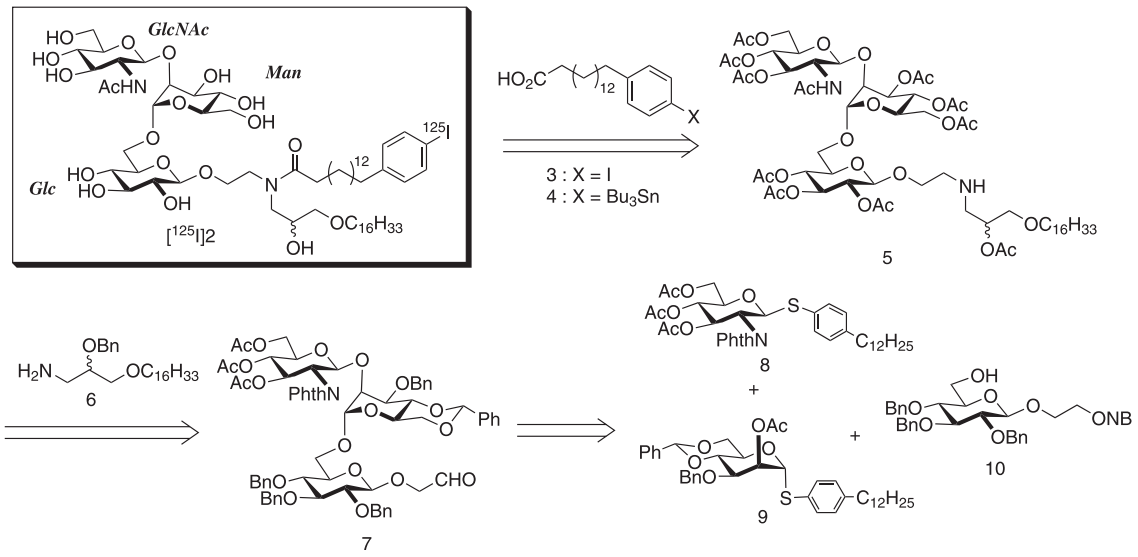
Next, the trisaccharide **7** was synthesized from the glucoside **10** by repeated glycosylation and further transformation of the functional group using the route depicted in Scheme 3.[13,14]

Glycosylation of acceptor **10** with the glycosyl donor **9** in the presence of *N*-iodosuccinimide and silver trifluoromethanesulfonate in dichloromethane yielded (2-nitrobenzyloxy)ethyl 2-*O*-acetyl-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (**16**) (84%). Conventional deacetylation of **16** gave the disaccharide **17**, which was used as a glycosyl acceptor (91%), in a subsequent glycosylation step, using **8** as the glycosyl donor, to afford 2-(2-nitrobenzyloxy)ethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→2)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (**18**) (91%). Selective cleavage of the *o*-nitrobenzyl group on the aglycon moiety of **18** via sunlight afforded **19** (88%), and subsequent treatment of **19** with the Dess–Martin reagent afforded the aldehyde **7** (96%).

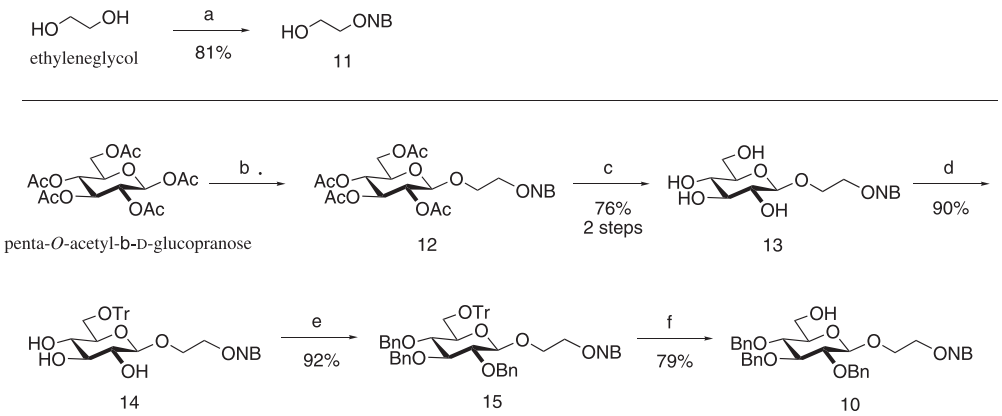
The amine **6** was synthesized from the commercially available glycidyl hexadecyl ether in three steps: nucleophilic attack of the azide ion onto the epoxide of the glycidyl hexadecyl ether, and subsequent protection of the generated hydroxyl group with a benzyl group to afford **20**, the hydrogenation of which afforded the desired amine **6** (Scheme 4).

Amine **6** and aldehyde **7** were then coupled by reductive amination with $NaB(CN)H_3$ to afford the coupling compound **21**. The amino group of **21** was protected with a *tert*-butyloxycarbonyl (Boc) group to give **22** (54%, two steps). Removal of the *N*-phthalimido group with hydrazine hydrate and subsequent acetylation gave **23**. Cleavage of the benzylidene and benzyl groups of **23**, via catalytic hydrogenolysis followed by acetylation, gave the peracetylated

[‡] Uptake amounts of [^{125}I]**1a–c** to cells were assessed as follows. GnT-V-transfected Widr cells were seeded at a density of 4×10^5 per well in 12-well plates and incubated for 24 h with Roswell Park Memorial Institute medium (RPMI) 1640 medium containing 10% fetal bovine serum. Afterward, the medium was replaced by Minimum Essential Medium (MEM) buffer (0.5 mL/well), and the cells were then pre-incubated for 30 min. After removing the buffer, MEM buffer solution of [^{125}I]**1a–c** (18.5 kBq/0.5 mL) was added, and cells were incubated at 37 °C with 5% CO_2. At each time point (0.5, 1, 3, 6, and 24 h), cells were washed with phosphate-buffered saline and lysed with 0.2 M NaOHaq. (0.7 mL/well). Radioactivity of the lysate was measured in Cobra II auto gamma counter (Packard, Detroit, MI, USA). Uptake profiles were evaluated by the radioactivity, of which the value was corrected on the basis of the protein concentration measured by bicinchoninic acid method.

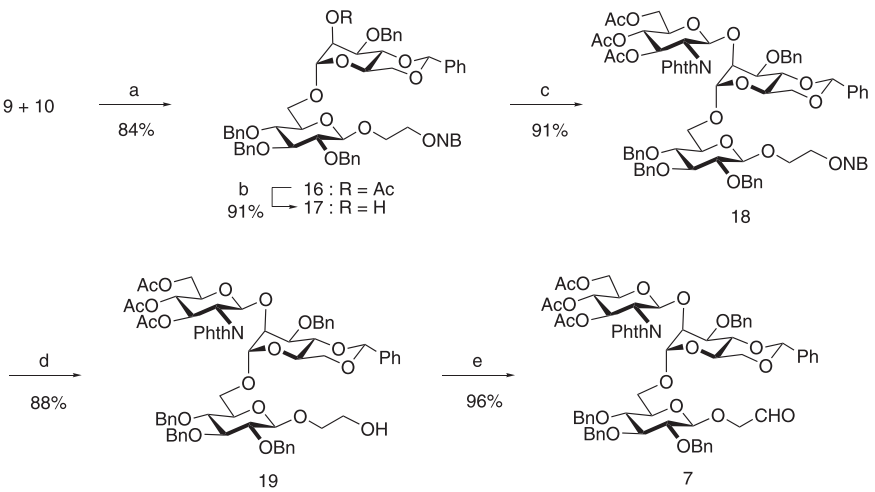


Scheme 1. Retrosynthetic analysis of the ^{125}I-radiolabeled trisaccharide [^{125}I]**2**.



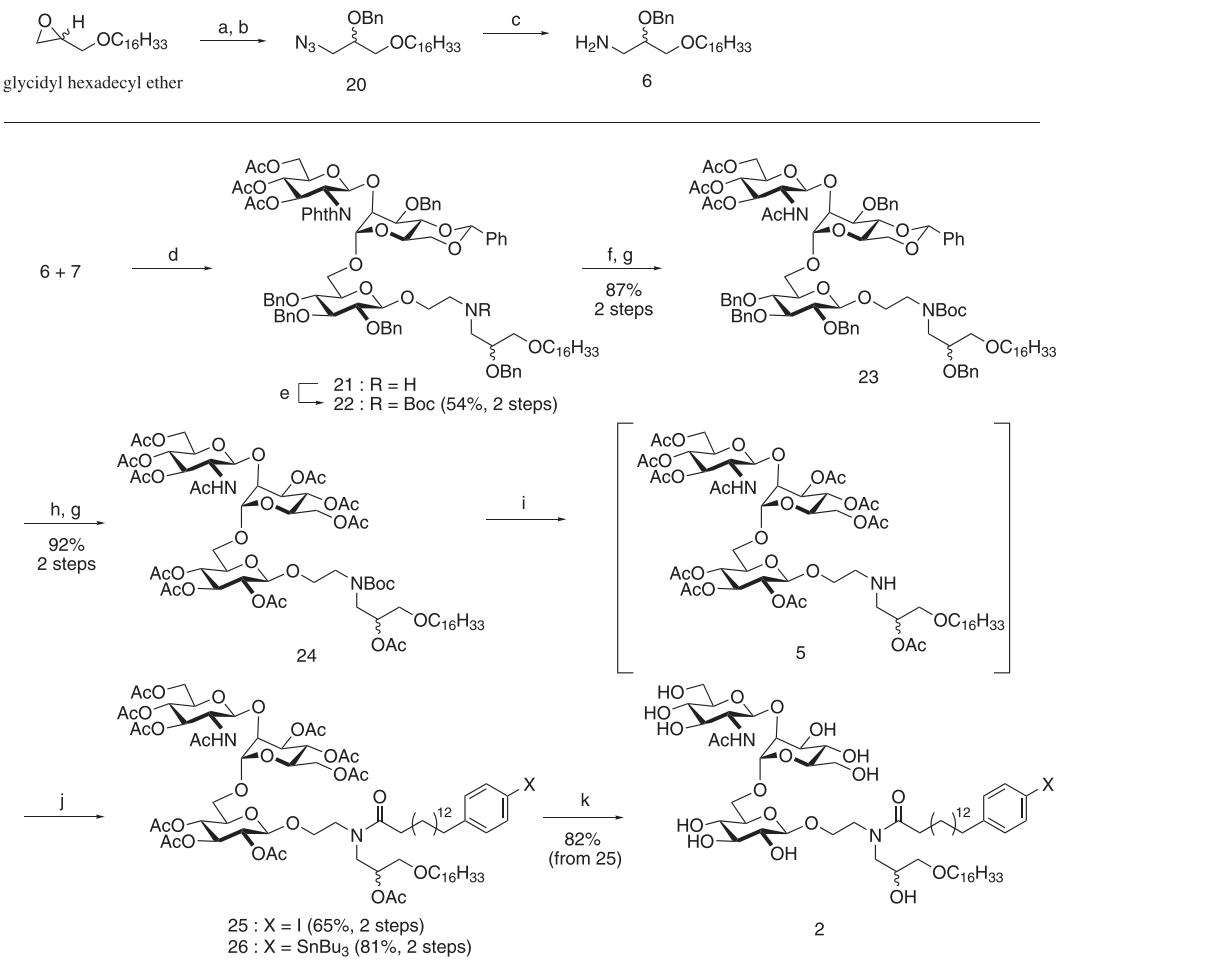
a: *o*-nitrobenzyl bromide, NaH, b: **11**, $BF_3 \cdot Et_2O$, CH_2Cl_2, c: NaOMe, MeOH, d: TrCl, DMAP, pyridine, e: $BnOC(=NH)CCl_3$, TMSOTf, MS 5A, 1,4-dioxane, f: HCl in 1,4-dioxane.

Scheme 2. Synthesis of the glucose derivative of intermediate **10**.



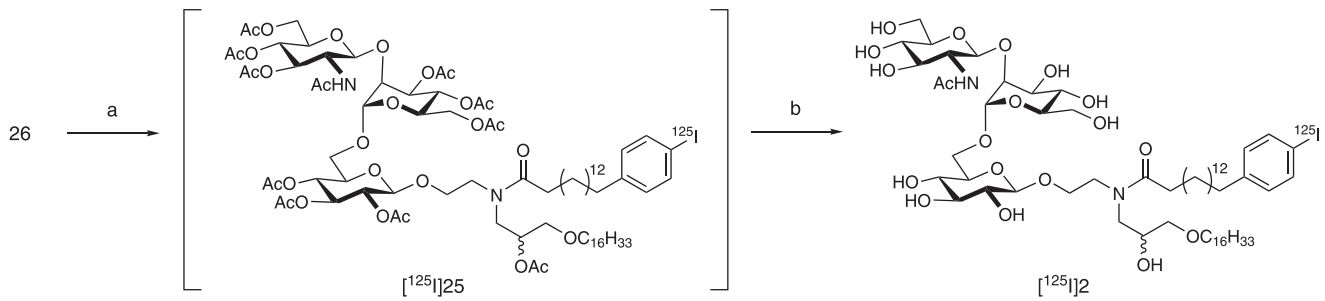
a: NIS, AgOTf, MS 4A, CH_2Cl_2, b: NaOMe, MeOH-toluene, c: **8**, NIS, AgOTf, MS4A, CH_2Cl_2, d: sunlight, $CHCl_3$, e: Dess-Martin periodinane, CH_2Cl_2.

Scheme 3. Synthesis of the trisaccharide intermediate **7**.



a: NaN_3, $Et_3N \cdot HCl$, DMF, b: BnBr, NaH, DMF, c: H_2, Pd-C, MeOH, d: $NaBH_3CN$, CH_2Cl_2, e: Boc_2O, DMAP, CH_2Cl_2, f: NH_2NH_2, EtOH, g: Ac_2O, pyridine, h: H_2, $Pd(OH)_2$-C, MeOH, i : MsOH, CH_2Cl_2, j: **3** or **4**, WSC, DMAP, CH_2Cl_2, k: NaOMe, MeOH.

Scheme 4. Synthesis of compound **2**.



a: [^{125}I]NaI, 5% H_2O_2aq., 0.1N HClaq., CH_3CN, b: NaOMe, MeOH

Scheme 5. Radiosynthesis of the target compound [^{125}I]**2**.

trisaccharide derivative **24**. The *N-tert*-butyloxycarbonyl group of **24** was cleaved by treatment with methanesulfonic acid to afford the secondary amine **5**, which was condensed with 15-(4-iodophenyl)pentadecanoic acid (**3**)[19] in the presence of 1-ethyl-3-(3′-dimethylaminopropyl)carbodiimide·HCl (WSC) and DMAP in dichloromethane to give **25** (65%, two steps). **25** was subsequently deacetylated to produce the nonradioactive compound **2** (82%). The synthesis of the precursor of [^{125}I]**2** (**26**), in which the tributyltin group was expected to be easily replaced with a radioiodine atom by iododestannylation, was performed by coupling **5** and the carboxylic acid **4**[19] (81%, two steps, Scheme 4).

Next, the tributyltin derivative **26** was transformed to the radiolabeled [^{125}I]**25** by an iododestannylation reaction using hydrogen peroxide as the oxidant.[20–22] Conventional

deacetylation of [^{125}I]**25** afforded the desired radioiodinated compound [^{125}I]**2**. The radiochemical identity of [^{125}I]**2** was verified by HPLC with co-injection of the nonradioactive **2**. A single radioactive peak of the final radioiodinated compound [^{125}I]**2** was observed at the same retention time as that of the nonradioactive **2**. The radioiodinated product was obtained in 49% radiochemical yield with a radiochemical purity of >95% after purification by HPLC (Scheme 5).

Conclusions

We successfully synthesized a novel glycolipid derivative **2** with a trisaccharyl moiety and a double-chained lipid moiety via the key intermediate **7**, which included a readily modified aglycon moiety. The ^{125}I-labeled derivative [^{125}I]**2** was directly synthesized from the tributyltin derivative **26** by iododestannylation and deacetylation. These methods are applicable to the synthesis and radiosynthesis of various complex glycolipids. In vitro and in vivo studies using [^{125}I]**2** are in progress, and the results will be published in due course.

Experimental

General

Infrared (IR) spectra were recorded on an FTIR-8300 diffraction grating infrared spectrophotometer (Shimadzu, Kyoto, Japan). ^{1}H, ^{13}C-NMR spectra were obtained on a JNM AL-300 spectrometer (JEOL, Tokyo, Japan) or unity INOVA-400 spectrometer (Varian, Palo Alto, CA, USA), and chemical shifts were reported in ppm using tetramethylsilane, $CDCl_3$, or C_5D_5N as the internal standard. Mass spectra (MS) were determined on a JMS-SX 102A QQ or JMS-GC-mate mass spectrometer (JEOL). Specific rotations were recorded on a SEPA-200 automatic digital polarimeter (Horiba, Kyoto, Japan). Silica gel 60 (70–230 mesh; Merck, Darmstadt, Germany) was used for open column chromatography. Flash column chromatography was performed using silica gel 60 (230–400 mesh; Merck) as a solid support for the immobile phase. Thin layer chromatography (TLC) and preparative TLC were conducted using Kieselgel 60F-254 plates (0.25 and 0.5 mm; Merck). Unless purification with silica gel gave adequately pure compounds, the compounds were further purified using a recycling HPLC (LC-908; JAI, Tokyo, Japan) equipped with a gel permeation chromatography (GPC) column (JAIGEL 1H and 2H, JAI). When possible, diastereomer mixtures were separated using a recycling HPLC (LC-908) equipped with a silica gel column (Si-10, 30 mm × 400 mm; Kusano, Tokyo, Japan), after the purification methods mentioned earlier.

Materials

Most reagents were obtained from Wako Pure Chemical Industries (Tokyo, Japan), Nacalai Tesque (Kyoto, Japan), and Aldrich Chemical (St. Louis, MO, USA).

2-(2-Nitrobenzyloxy)ethanol (11)

Ethyleneglycol (100 mL) was added dropwise to sodium hydride (2.42 g, 55.5 mmol) at 0 °C, and the mixture was stirred for 30 min after elevating the temperature to ca. 20 °C. *o*-Nitrobenzyl bromide (10.0 g, 46.3 mmol) was added to the reaction mixture, which was then stirred for another 5.5 h at room temperature. The reaction was quenched by pouring the mixture into ice water, which was then extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 50/1 to ethyl acetate) and further refined by distillation (180 °C, 2 mmHg) to afford compound **11** (6.40 g, 70%) as a yellow oil. The NMR spectra of **11** were in accord with those published.[18] ^{1}H-NMR (400 MHz, $CDCl_3$, δ): 2.11 (br s, 1H), 3.70–3.72 (m, 2H), 3.82–3.84 (m, 2H), 4.95 (s, 2H), 7.43–7.48 (m, 1H), 7.63–7.67 (m, 1H), 7.77–7.79 (m, 1H), 8.06 (dd, J = 1.3, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 61.8, 69.7, 72.3, 124.7, 128.1, 128.7, 133.6, 134.6, 147.4.

2-(2-Nitrobenzyloxy)ethyl β-D-glucopyranoside (13)

Boron trifluoride etherate complex (2.57 mL, 20.3 mmol) was added to a solution of penta-*O*-acetyl-β-D-glucopyranoside (7.93 g, 20.3 mmol) and **11** (6.01 g, 30.5 mmol) in CH_2Cl_2 (100 mL) at 0 °C, and the mixture was stirred for 10 h at room temperature. The reaction was quenched by pouring the reaction mixture into ice water, which was then extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (n-hexane/ethyl acetate = 2/1) to afford a mixture of **11** and 2-(2-nitrophenoxy)ethyl 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranoside (**12**) (10.6 g). A solution of the mixture in methanol (100 mL) was treated with sodium methoxide (28% in methanol, 4 mL) for 2 h at room temperature. The reaction mixture was neutralized by adding Dowex 50 (H^+) (30.4 g), and then the filtrate was concentrated under vacuum. The residue was purified using silica gel column chromatography (chloroform/methanol/H_2O = 9/1/0.08) to afford compound **13** (5.55 g, 76%, two steps). $[\alpha]_D = -14.6°$ (c = 1.00, MeOH). ^{1}H-NMR (400 MHz, C_5D_5N, δ): 3.79 (br t, J = 5.7 Hz, 2H, –OCH_2), 3.94 (ddd, J = 2.4, 5.3, 9.3 Hz, 1H, H-5), 3.98 (br dt, J = 5.7, 11.2 Hz, 1H, –OCH_2), 4.05 (br t, J = 7.7 Hz, 1H, H-2), 4.22–4.28 (m, 2H, H-3, H-4), 4.28 (br dt, J = 5.7, 11.2 Hz, 1H, –OCH_2), 4.38 (dd, J = 5.3, 11.7 Hz, 1H, H-6), 4.55 (dd, J = 2.4, 11.7 Hz, 1H, H-6), 4.91 (d, J = 7.7 Hz, 1H, H-1), 4.95 (s, 2H, –ONB), 6.42 (br, 1H, –OH), 7.17–7.32 (m, 3H, –OH), 7.30 (br t, J = 8.1 Hz, 1H), 7.50 (dt, J = 1.3, 7.9 Hz, 1H), 7.90 (dd, J = 1.1, 7.9 Hz, 1H), 8.03 (dd, J = 1.3, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, C_5D_5N) δ: 62.8 (C-6), 68.9 (–OCH_2), 69.8 (–ONB), 70.9 (–OCH_2), 71.6 (C-4), 75.2 (C-2), 78.56 (C-3), 78.61 (C-5), 104.9 (C-1), 124.0, 124.8, 128.2, 129.2, 133.9, 147.6. IR (KBr) ν: 3393, 2924, 2878, 2361, 2341, 1611, 1522, 1360, 1340, 1298, 1107, 1074 cm^{-1}. FAB-MS *m/z*: 382 ($M + Na^+$). HRMS *m/z*: 382.1111 (calcd for $C_{15}H_{21}NO_9Na$: 382.1114). Anal. calcd for $C_{15}H_{21}NO_9$: C, 50.14; H, 5.89; N, 3.90; found: C, 50.21; H, 5.61; N, 3.83.

2-(2-Nitrobenzyloxy)ethyl 6-*O*-trityl-β-D-glucopyranoside (14)

Trityl chloride (8.27 g, 29.7 mmol) and DMAP (catalytic amount) were added to a solution of **13** (5.33 g, 14.8 mmol) in pyridine (100 mL), and the mixture was stirred for 6 h under reflux. The reaction mixture was concentrated in vacuo and poured into ice water, which was then extracted with chloroform. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (chloroform/methanol = 60/1) to afford **14** (8.03 g, 90%) as an amorphous powder. $[\alpha]_D = -27.1°$ (c = 1.10, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 3.09 (d, J = 1.8 Hz, 1H, –OH), 3.36–3.45 (m, 6H), 3.50–3.57 (m, 2H), 3.72–3.84 (m, 3H), 4.05–4.10 (m, 1H), 4.34 (d, J = 7.7 Hz, 1H, H-1), 4.92 (s, 2H), 7.22 (tt, J = 1.3, 7.1 Hz, 3H), 7.28 (br t, J = 7.1 Hz, 6H), 7.39 (br t, J = 8.1 Hz, 1H), 7.44 (br d, J = 8.4 Hz, 6H), 7.57 (dt, J = 1.3, 7.9 Hz, 1H), 7.75 (dd, J = 1.1, 7.9 Hz, 1H), 8.00 (dd, J = 1.3, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 64.2 (C-6), 68.8 (–OCH_2), 69.8 (–ONB), 70.3 (–OCH_2), 71.9 (C-4), 73.5 (C-5), 74.1 (C-2), 76.2

(C-3), 87.0 (–CPh_3), 102.8 (C-1), 124.7, 127.2 (3C), 127.9 (6C), 128.1, 128.6 (6C), 128.8, 133.6, 134.5, 143.6 (3C), 147.4. IR ($CHCl_3$) ν: 3593, 3503, 3028, 3017, 2930, 2883, 1526, 1448, 1342, 1067 cm^{-1}. FAB-MS *m/z*: 624 ($M + Na^+$). HRMS *m/z*: 624.2206 (calcd for $C_{34}H_{35}NO_9Na$: 624.2210).

2-(2-Nitrobenzyloxy)ethyl 2,3,4-*O*-benzyl-6-*O*-trityl-β-D-glucopyranoside (15)

A catalytic amount of trimethylsilyl trifluoromethanesulfonate was added to a suspension of **14** (31.0 mg, 51.5 μmol), benzyl 2,2,2-oxy-trichloroacetimidate (38.5 μL, 0.206 mmol), and molecular sieves 5A (MS 5A) (100 mg) in 1,4-dioxane (2 mL). After being stirred for 1 h at room temperature, the reaction mixture was poured into a saturated aqueous sodium bicarbonate solution and extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using preparative thin layer silica gel chromatography (*n*-hexane/ethyl acetate = 3/1) to afford **15** (41.1 mg, 92%) as an amorphous powder. $[\alpha]_D = +8.1^\circ$ ($c = 1.15$, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 3.24 (dd, $J = 3.8$, 10.1 Hz, 1H, H-6), 3.42 (ddd, $J = 1.8$, 3.8, 9.9 Hz, 1H, H-5), 3.56–3.65 (m, 3H, H-2, H-3, H-6), 3.81–3.96 (m, 4H, H-4, –OCH_2, –OCH_2), 4.23–4.28 (m, 1H, –OCH_2), 4.37 (d, $J = 10.3$ Hz, 1H, –OCH_2), 4.54 (d, $J = 7.3$ Hz, 1H, H-1), 4.70 (d, $J = 10.3$ Hz, 1H, –OCH_2), 4.78 (d, $J = 11.0$ Hz, 1H, –OCH_2), 4.79 (d, $J = 10.6$ Hz, 1H, –OCH_2), 4.90 (d, $J = 10.6$ Hz, 1H, –OCH_2), 4.99 (s, 2H, –ONB), 5.04 (d, $J = 11.0$ Hz, 1H, –OCH_2), 6.85–6.88 (m, 2H), 7.15–7.39 (m, 23H), 7.43–7.52 (m, 7H), 7.84 (dd, $J = 1.1$, 7.9 Hz, 1H), 8.05 (dd, $J = 1.3$, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 62.4 (C-6), 68.7, 69.8, 70.5, 74.6(C-5), 74.8 (–OBn), 75.0 (–OBn), 75.9 (–OBn), 77.8 (C-4), 82.5 (C-2), 84.6 (C-3), 86.3 (–CPh_3), 103.8 (C-1), 124.6, 126.9 (3C), 127.6, 127.6, 127.8 (6C), 128.0 (2C), 128.0 (2C), 128.2 (3C), 128.2 (3C), 128.3 (2C), 128.4 (2C), 128.5, 128.8 (5C), 133.7, 135.2, 137.8, 138.5, 138.6, 143.9 (3C), 147.0. IR ($CHCl_3$) ν: 3088, 3065, 3032, 3011, 2860, 1526, 1448, 1342, 1234, 1094, 1070 cm^{-1}. FAB-MS *m/z*: 894 ($M + Na^+$). HRMS *m/z*: 894.3622 (calcd for $C_{55}H_{53}NO_9Na$: 894.3618).

2-(2-Nitrobenzyloxy)ethyl 2,3,4-*O*-benzyl-β-D-glucopyranoside (10)

A solution of 4 M HCl in 1,4-dioxane (4 mL) was added to a solution of **15** (802.9 mg, 0.921 mmol) in 1,4-dioxane (28 mL), and the mixture was stirred for 4 h at room temperature. The reaction mixture was poured into a saturated aqueous sodium bicarbonate solution, which was then extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 2/1) to afford **10** (457.1 mg, 79%) as an amorphous powder. $[\alpha]_D = +6.9^\circ$ ($c = 0.99$, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 1.96 (br, 1H, –OH), 3.38 (ddd, $J = 2.7$, 4.6, 9.5 Hz, 1H, H-5), 3.46 (dd, $J = 7.9$, 9.2 Hz, 1H, H-2), 3.58 (t, $J = 9.5$ Hz, 1H, H-4), 3.66–3.88 (m, 6H, H-3, –OCH_2–CH_2O–, H-6), 4.08–4.13 (m, 1H, H-6), 4.53 (d, $J = 7.9$ Hz, 1H, H-1), 4.64 (d, $J = 11.0$ Hz, 1H), 4.72 (d, $J = 11.0$ Hz, 1H), 4.81 (d, $J = 11.0$ Hz, 1H), 4.87 (d, $J = 11.0$ Hz, 1H), 4.93 (d, $J = 10.8$ Hz, 1H), 4.94 (s, 2H), 4.97 (d, $J = 11.0$ Hz, 1H), 7.22–7.35 (m, 15H), 7.38–7.42 (m, 1H), 7.53 (dt, $J = 1.3$, 7.9 Hz, 1H), 7.79 (dd, $J = 1.1$, 7.9 Hz, 1H), 8.05 (dd, $J = 1.3$, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 62.0 (C-6), 69.2 (–OCH_2), 69.7 (–ONB), 70.3 (–OCH_2), 74.8 (–OBn), 75.1 (2C, C-5, –OBn), 75.2 (–OBn), 77.4 (C-4), 82.2 (C-2), 84.4 (C-3), 103.9 (C-1), 124.6, 127.59, 127.62, 127.87 (2C), 127.89, 127.91 (2C), 127.94 (2C), 128.1, 128.3 (2C), 128.4 (2C), 128.5 (2C), 128.6, 133.6, 135.0, 137.9, 138.4, 138.5, 147.1. IR ($CHCl_3$) ν: 3589, 3032, 3011, 2870, 2401, 1526, 1342, 1234, 1198, 1072 cm^{-1}. FAB-MS *m/z*: 652 ($M + Na^+$). HRMS *m/z*: 652.2523 (calcd for $C_{36}H_{39}NO_9Na$: 652.2517).

2-(2-Nitrobenzyloxy)ethyl 2-*O*-acetyl-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (16)

A suspension of **10** (2.03 g, 3.07 mmol), **9** (2.08 g, 3.30 mmol), and molecular sieves 4A (MS 4A) (20 g) in CH_2Cl_2 (60 mL) was stirred for 30 min at −50 °C. Thereafter, AgOTf (796.6 mg, 3.10 mmol) and *N*-iodosuccinimide (1.68 g, 7.47 mmol) were added to initiate the reaction. After being stirred for another 30 min at −20 °C, the mixture was filtered through Celite®. The filtrate was successively washed with a saturated aqueous sodium thiosulfate solution and brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 3/1) to afford **16** (2.62 g, 84%) as an amorphous powder. $[\alpha]_D = +25.6^\circ$ ($c = 1.03$, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 2.15 (s, 1H, OAc), 3.39–3.50 (m, 3H, Glc-2, Glc-4, –OCH_2), 3.54–3.58 (m, 1H, Man-6), 3.64–3.83 (m, 6H, Glc-3, –OCH_2, Man-5, –OCH_2, Glc-6), 3.90 (dt, $J = 4.6$, 10.1 Hz, 1H, Glc-5), 3.96 (dd, $J = 3.5$, 9.9 Hz, 1H, Man-3), 4.02–4.07 (m, 2H, Man-4, Man-6), 4.21 (dd, $J = 4.4$, 9.9 Hz, 1H, Glc-6), 4.45 (d, $J = 7.9$ Hz, 1H, Glc-1), 4.50 (d, $J = 11.0$ Hz, 1H), 4.64 (d, $J = 12.3$ Hz, 1H), 4.71 (d, $J = 11.4$ Hz, 2H), 4.78 (d, $J = 10.8$ Hz, 1H), 4.83 (s, 3H, Man-1, –OCH_2), 4.86 (d, $J = 11.0$ Hz, 1H), 4.95 (d, $J = 11.0$ Hz, 1H), 5.00 (d, $J = 11.0$ Hz, 1H), 5.43 (dd, $J = 1.6$, 3.3 Hz, 1H, Man-2), 5.61 (s, 1H, PhCH<), 7.19–7.39 (m, 24H), 7.44–7.49 (m, 3H), 7.76 (dd, $J = 1.1$, 7.7 Hz, 1H), 8.04 (dd, $J = 1.3$, 8.2 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 21.0, 63.9 (Man-5), 66.3 (Glc-6), 68.6 (Man-6), 68.9 (–OCH_2), 69.4 (Man-2), 69.6 (–ONB), 70.4 (–OCH_2), 71.9 (–OBn), 73.4 (Man-3), 74.0 (Glc-5), 74.7 (–OBn), 75.0 (–OBn), 75.7 (–OBn), 77.7 (Glc-4), 78.2 (Man-4), 82.8 (Glc-2), 84.6 (Glc-3), 98.6 (Man-1), 101.4 (PhCH<), 103.6 (Glc-1), 124.6, 126.0 (2C), 127.6, 127.65 (2C), 127.71 (2C), 127.9 (5C), 128.0 (2C), 128.1 (2C), 128.28 (3C), 128.31 (2C), 128.4 (2C), 128.47 (2C), 128.51, 128.8, 133.6, 135.2, 137.5, 137.8, 137.9, 138.4, 138.5, 147.0, 170.1. IR ($CHCl_3$) ν: 3090, 3067, 3030, 3020, 2862, 1746, 1526, 1356, 1234, 1096, 1069 cm^{-1}. FAB-MS *m/z*: 1034 ($M + Na^+$). HRMS *m/z*: 1034.3942 (calcd for $C_{58}H_{61}NO_{15}Na$: 1034.3939).

2-(2-Nitrobenzyloxy)ethyl 3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (17)

Sodium methoxide (28% in methanol, 471 μL) was added to a solution of **16** (2.39 g, 2.36 mmol) in a mixture of toluene (10 mL) and methanol (50 mL), and then the mixture was stirred for 1 h at room temperature. The reaction mixture was neutralized with Dowex 50 (H^+) and filtered. The filtrate was concentrated in vacuo, and the residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 2/1) to afford **17** (2.08 g, 91%). $[\alpha]_D = +38.2^\circ$ ($c = 1.14$, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 2.63 (s, 1H, –OH), 3.41–3.49 (m, 3H, Glc-2, Glc-4, Glc-5), 3.61–3.69 (m, 2H, Glc-3, –OCH_2), 3.73–3.91 (m, 7H, Glc-6, Man-3, Man-5, Man-6, –OCH_2), 4.04–4.13 (m, 3H, Man-2, Man-4, –OCH_2), 4.22 (dd, $J = 3.8$, 9.2 Hz, 1H, Man-6), 4.46 (d, $J = 7.9$ Hz, 1H, Glc-1), 4.54 (d, $J = 10.8$ Hz, 1H, –OBn), 4.71 (d, $J = 11.0$ Hz, 1H, –OBn), 4.72 (d, $J = 12.1$ Hz, 1H, –OBn), 4.79

(d, J = 10.8 Hz, 1H, –OBn), 4.84 (d, J = 12.1 Hz, 1H, –OBn), 4.86 (s, 2H, –ONB), 4.87 (d, J = 10.8 Hz, 1H, –OBn), 4.94 (s, 1H, Man-1), 4.95 (d, J = 10.8 Hz, 1H, –OBn), 5.00 (d, J = 11.0 Hz, 1H, –OBn), 5.60 (s, 1H, PhCH<), 7.22–7.39 (m, 24H), 7.44–7.50 (m, 3H), 7.77 (dd, J = 1.1, 7.9 Hz, 1H), 8.04 (dd, J = 1.3, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 63.4 (Man-5), 66.1 (Glc-6), 68.8 (Man-6), 68.9 (–OCH_2), 69.6 (–ONB), 69.8 (Man-2), 70.4 (–OCH_2), 72.9 (–OBn), 74.2 (Glc-5), 74.7 (–OBn), 75.1 (–OBn), 75.2 (Man-3), 75.7 (–OBn), 77.6 (Glc-4), 78.8 (Man-4), 82.2 (Glc-2), 84.6 (Glc-3), 100.1 (Man-1), 101.5 (PhCH<), 103.7 (Glc-1), 124.6, 126.0 (2C), 127.6, 127.7, 127.75, 127.83 (2C), 127.9 (6C), 128.0 (2C), 128.1 (2C), 128.3 (2C), 128.4 (2C), 128.45 (2C), 128.49 (2C), 128.6, 128.8, 133.6, 135.2, 137.6, 137.86, 137.92, 138.4, 138.5, 147.0. IR ($CHCl_3$) ν: 3568, 3090, 3067, 3024, 2916, 2874, 1526, 1454, 1342, 1097, 1069, 1030 cm^{-1}. FAB-MS m/z: 992 (M + Na$^+$). HRMS m/z: 992.3837 (calcd for $C_{56}H_{59}NO_{14}Na$: 992.3833).

2-(2-Nitrobenzyloxy)ethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-gluco-pyranosyl-(1→2)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (18)

A suspension of **17** (2.46 g, 2.54 mmol), **7** (1.93 g, 2.77 mmol), and MS 4A (50 g) in CH_2Cl_2 (80 mL) was stirred for 30 min at −50 °C, and then AgOTf (671.1 mg, 2.61 mmol) and *N*-iodosuccinimide (1.43 g, 6.36 mmol) were added to initiate the reaction. After being stirred for another 1.5 h at −20 °C, the mixture was filtered through Celite®. The filtrate was neutralized with a saturated aqueous sodium bicarbonate solution, successively washed with a saturated aqueous sodium thiosulfate solution and brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 2/1) to afford **18** (3.27 g, 93%). $[\alpha]_D$ = +19.4° (c = 1.04, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 1.90, 2.02, and 2.06 (each s, 3H, Ac), 2.97 (t, J = 10.1 Hz, 1H, Man-6), 3.29–3.33 (m, 2H, Glc-4, Glc-5), 3.40 (dd, J = 7.9, 9.0 Hz, 1H, Glc-2), 3.49–3.55 (m, 2H, Man-5, Man-6), 3.61–3.65 (m, 3H, Glc-3, Glc-6, Man-6), 3.69 (dd, J = 5.1, 8.4 Hz, 1H, –OCH_2), 3.78–3.86 (m, 4H, Man-3. Man-4, –OCH_2), 4.00 (ddd, 1H, J = 2.4, 4.8, 10.3 Hz, 1H, GlcN-5), 4.17 (dd, J = 1.6, 2.7 Hz, 1H, Man-2), 4.25 (dd, J = 2.4, 12.3 Hz, 1H, GlcN-6), 4.27 (dd, J = 4.4, 8.4 Hz, 1H, –OCH_2), 4.34 (d, J = 11.4 Hz, 1H, –OBn), 4.35 (dd, J = 4.8, 12.3 Hz, 1H, GlcN-6), 4.46 (d, J = 7.9 Hz, 1H, Glc-1), 4.50 (dd, J = 8.6, 11.0 Hz, 1H, GlcN-2), 4.62 (d, J = 1.6 Hz, 1H, Man-1), 4.67 (d, J = 12.5 Hz, 1H, –OBn), 4.70 (d, J = 11.0 Hz, 1H, –OBn), 4.73 (d, J = 12.5 Hz, 1H, –OBn), 4.74 (d, J = 11.4 Hz, 1H, –OBn), 4.77 (d, J = 10.8 Hz, 1H, –OBn), 4.88 (s, 2H, –ONB), 4.94 (d, J = 10.8 Hz, 1H, –OBn), 5.02 (d, J = 11.0 Hz, 1H, –OBn), 5.21 (dd, J = 9.2, 10.1 Hz, 1H, GlcN-4), 5.41 (s, 1H, PhCH<), 5.45 (d, J = 8.6 Hz, 1H, GlcN-1), 5.90 (dd, J = 9.2, 11.0 Hz, 1H, GlcN-3), 7.10–7.40 (m, 26H), 7.48 (dt, J = 1.3, 7.9 Hz, 1H), 7.71–7.73 (m, 2H), 7.77 (dd, J = 1.1, 7.9 Hz, 1H), 7.84 (br, 2H), 8.04 (dd, J = 1.3, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 20.5, 20.6, 20.8, 54.4 (GlcN-2), 62.2 (GlcN-6), 63.8 (Man-5), 66.5 (Glc-6), 68.3 (Man-6), 69.2 (GlcN-4), 69.4 (–OCH_2), 69.6 (–ONB), 70.3 (GlcN-3), 70.4 (–OCH_2), 71.2 (–OBn), 72.0 (GlcN-5), 72.7 (Man-3), 74.3 (Glc-5), 74.6 (Man-2), 74.7 (–OBn), 74.9 (–OBn), 75.8 (–OBn), 77.1 (Glc-4), 78.0 (Man-4), 82.3 (Glc-2), 84.5 (Glc-3), 96.3 (GlcN-1), 98.2 (Man-1), 101.3 (PhCH<), 104.0 (Glc-1), 123.4, 124.6, 126.0 (2C), 127.58, 127.61, 127.7 (3C), 127.79 (4C), 127.83, 127.91 (3C), 127.94 (3C), 128.0 (3C), 128.26 (2C), 128.29 (2C), 128.36 (2C), 128.43 (2C), 128.5 (3C), 128.7, 133.6, 134.2, 135.1, 137.6, 137.8, 138.2, 138.3, 138.4, 147.0, 169.4, 170.2, 170.7. IR ($CHCl_3$) ν: 3481, 3067, 3030, 3017, 2914, 2870, 1751, 1719, 1526, 1389, 1367, 1238, 1084, 1040 cm^{-1}. FAB-MS m/z: 1409 (M + Na$^+$). HRMS m/z: 1409.4904 (calcd for $C_{76}H_{78}N_2O_{23}Na$: 1409.4893).

2-Hydroxyethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→2)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (19)

A solution of **18** (498.7 mg, 0.359 mmol) in $CHCl_3$ (359 mL) was irradiated with sunlight for 4 h, and then the solvent was evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 2/3) to afford **19** (396.6 mg, 88%). $[\alpha]_D$ = +15.1° (c = 1.13, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 1.90, 2.05, and 2.06 (each s, 3H, Ac), 2.79 (br t, J = 7.0 Hz, 1H, –OH), 3.04 (t, J = 10.3 Hz, 1H, Man-6), 3.28 (t, J = 9.7 Hz, 1H, Glc-4), 3.37–3.41 (m, 1H, Glc-5), 3.41 (dd, J = 7.9, 9.2 Hz, 1H, Glc-2), 3.47–3.56 (m, 3H, Man-5, Glc-6), 3.58–3.74 (m, 4H, Glc-3, Man-6, –OCH_2), 3.82–3.89 (m, 3H, Man-3, Man-4, –OCH_2), 3.94–4.00 (m, 2H, GlcN-5, –OCH_2), 4.19 (br s, 1H, Man-2), 4.25 (dd, J = 2.6, 12.3 Hz, 1H, GlcN-6), 4.33 (dd, J = 4.8, 12.3 Hz, 1H, GlcN-6), 4.38 (d, J = 11.0 Hz, 1H, –OBn), 4.42 (d, J = 7.9 Hz, 1H, Glc-1), 4.49 (dd, J = 8.6, 11.0 Hz, 1H, GlcN-2), 4.58 (d, J = 1.5 Hz, 1H, Man-1), 4.66 (d, J = 12.5 Hz, 1H, –OBn), 4.74 (d, J = 12.5 Hz, 1H, –OBn), 4.77 (d, J = 11.0 Hz, 2H, –OBn × 2), 4.80 (d, J = 11.2 Hz, 1H, –OBn), 4.92 (d, J = 11.2 Hz, 1H, –OBn), 4.95 (d, J = 10.8 Hz, 1H, –OBn), 5.20 (dd, J = 9.2, 10.1 Hz, 1H, GlcN-4), 5.43 (s, 1H, PhCH<), 5.46 (d, J = 8.6 Hz, 1H, GlcN-1), 5.89 (dd, J = 9.2, 11.0 Hz, 1H, GlcN-3), 7.13–7.41 (m, 25H), 7.69 (br, 2H), 7.84 (br, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 20.5, 20.7, 20.8, 54.4 (GlcN-2), 62.17 (GlcN-6), 62.23 (–OCH_2), 63.9 (Man-5), 66.4 (Glc-6), 68.3 (Man-6), 69.2 (GlcN-4), 70.4 (GlcN-3), 71.2 (–OBn), 71.9 (GlcN-5), 73.1 (Man-3), 73.5 (Glc-5), 73.6 (–OCH_2), 74.7 (Man-2), 74.9 (–OBn), 75.0 (–OBn), 75.7 (–OBn), 77.5 (Glc-5), 77.9 (Man-4), 82.3 (Glc-2), 84.6 (Glc-3), 96.4 (GlcN-1), 97.8 (Man-1), 101.4 (PhCH<), 104.3 (Glc-1), 123.4, 126.0 (3C), 127.5, 127.7 (3C), 127.76, 127.81 (3C), 127.9 (3C), 128.0 (2C), 128.1 (2C), 128.2 (3C), 128.4 (3C), 128.45 (3C), 128.47 (3C), 128.8, 134.2, 137.5, 137.7, 138.2, 138.28, 138.33, 169.5, 170.2, 170.8. IR ($CHCl_3$) ν: 3699, 3013, 2864, 2399, 2363, 2340, 1751, 1719, 1387, 1367, 1238, 1086 cm^{-1}. FAB-MS m/z: 1274 (M + Na$^+$). HRMS m/z: 1274.4580 (calcd for $C_{69}H_{73}NO_{21}Na$: 1274.4573).

2-Oxoethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→2)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (7)

Dess–Martin reagent (51.3 mg, 0.121 mmol) was added to a solution of **19** (100.9 mg, 80.6 μmol) in CH_2Cl_2 (3 mL), and the mixture was stirred for 1 h at room temperature. Subsequently, a second amount of Dess–Martin reagent (51.3 mg, 0.121 mmol) was added to the reaction mixture, which was stirred for another 1 h. The reaction was quenched by pouring it into a saturated aqueous sodium bicarbonate solution, which was then extracted with chloroform. The organic layer was successively washed with a saturated aqueous sodium thiosulfate solution and brine, dried over sodium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 1/1) to afford **7** (96.8 mg, 96%). $[\alpha]_D$ = +21.7° (c = 0.98, $CHCl_3$). ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 1.90 (s, 3H, Ac), 2.06 (s, 6H, Ac x2), 3.03 (t, J = 10.3 Hz, 1H, Man-6), 3.31–3.33 (m, 2H, Glc-4,

Glc-5), 3.45–3.51 (m, 2H, Man-5, Glc-6), 3.47 (dd, J = 7.9, 9.2 Hz, 1H, Glc-2), 3.57–3.67 (m, 3H, Glc-3, Glc-6, Man-6), 3.78 (dd, J = 2.9, 10.1 Hz, 1H, Man-3), 3.85 (t, J = 10.1 Hz, 1H, Man-4), 4.01 (ddd, J = 2.4, 4.8, 10.1 Hz, 1H, GlcN-5), 4.13 (dd, J = 1.5, 2.9 Hz, 1H, Man-2), 4.27 (dd, J = 2.4, 12.2 Hz, 1H, GlcN-6), 4.30 (br d, J = 17.8 Hz, 1H, –OCH_2), 4.34 (d, J = 11.0 Hz, 1H, –OBn), 4.36 (dd, J = 4.8, 12.2 Hz, 1H, GlcN-6), 4.45 (d, J = 7.9 Hz, 1H, Glc-1), 4.49 (dd, J = 8.4, 11.0 Hz, 1H, GlcN-2), 4.56 (d, J = 1.5 Hz, 1H, Man-1), 4.57 (dd, J = 1.3, 17.8 Hz, 1H, –OCH_2), 4.69 (d, J = 12.5 Hz, 1H, –OBn), 4.74 (d, J = 11.0 Hz, 1H, –OBn), 4.75 (d, J = 12.5 Hz, 1H, –OBn), 4.79 (d, J = 11.0 Hz, 1H, –OBn), 4.80 (d, J = 10.8 Hz, 1H, –OBn), 4.97 (d, J = 10.8 Hz, 1H, –OBn), 5.03 (d, J = 11.0 Hz, 1H, –OBn), 5.20 (dd, J = 9.2, 10.1 Hz, 1H, GlcN-4), 5.42 (d, J = 8.4 Hz, 1H, GlcN-1), 5.43 (s, 1H, PhCH<), 5.85 (dd, J = 9.2, 11.0 Hz, 1H, GlcN-3), 7.12–7.42 (m, 25H), 7.70 (br, 2H), 7.84 (br, 2H), 9.68 (br d, J = 0.7 Hz, 1H, –CHO). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 20.5, 20.7, 20.8, 54.4 (GlcN-2), 62.2 (GlcN-6), 63.9 (Man-5), 65.9 (Glc-6), 68.3 (Man-6), 69.1 (GlcN-4), 70.4 (GlcN-3), 71.3 (–OBn), 71.9 (GlcN-5), 72.8 (Man-3), 73.8 (Glc-5), 74.85 (Man-2), 74.92 (2C, –OBn, –OCH_2), 75.1 (–OBn), 75.8 (–OBn), 77.1 (Glc-4), 78.0 (Man-4), 82.0 (Glc-2), 84.3 (Glc-3), 96.4 (GlcN-1), 97.8 (Man-1), 101.4 (PhCH<), 103.9 (Glc-1), 123.4, 126.0 (2C), 127.6, 127.7 (2C), 127.77 (3C), 127.84, 127.91, 127.94 (2C), 128.1 (3C), 128.15 (3C), 128.24 (3C), 128.42 (3C), 128.44 (4C), 128.8, 131.5, 134.2 (2C), 137.5, 137.7, 138.1, 138.2, 138.3, 169.5, 170.2, 170.8, 199.3. IR ($CHCl_3$) ν: 3067, 3028, 3018, 2858, 1749, 1719, 1603, 1387, 1367, 1236, 1088 cm^{-1}. FAB-MS *m/z*: 1272 ($M + Na^+$). HRMS *m/z*: 1272.4420 (calcd for $C_{69}H_{71}NO_{21}Na$: 1272.4416).

1-Azide-2-benzyloxypropyl hexadecyl ether (20)

Sodium azide (69.8 mg, 1.07 mmol) and triethylamine hydrochloride (147.7 mg, 1.07 mmol) were added to a solution of glycidyl hexadecyl ether (160.2 mg, 0.537 mmol) in DMF (8 mL), and the mixture was stirred for 5 h at 100 °C. The reaction mixture was poured into a saturated aqueous sodium bicarbonate solution, which was then extracted with ethyl acetate. The organic layer was washed with distilled water, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 7/1) to afford a crude mixture containing 1-azido-3-(hexadecyloxy)-2-propanol (156.4 mg). Sodium hydride (31.3 mg, 0.717 mmol) and benzyl bromide (80 μL, 0.673 mmol) were added to a solution of the mixture (151.9 mg) in DMF (5 mL) at 0 °C. The mixture was stirred for 2 h at room temperature, and the reaction was quenched by pouring the mixture into ice water, which was then extracted with diethyl ether. The organic layer was washed with distilled water, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 50/1) to afford **20** (145.9 mg, 76%, two steps). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.88 (t, J = 6.9 Hz, 3H), 1.25 (m, 26H), 1.53 (m, 2H), 3.38 (dd, J = 6.0, 12.9 Hz, 1H), 3.41 (dd, J = 4.3, 12.9 Hz, 1H), 3.42 (t, J = 6.6 Hz, 2H), 3.49 (dd, J = 6.0, 10.0 Hz, 1H), 3.54 (dd, J = 5.0, 10.0 Hz, 1H), 3.72 (br quint, J = 6.0 Hz, 1H), 4.68 (s, 2H), 7.27–7.37 (m, 5H). ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 14.1, 22.7, 26.1, 29.4, 29.5, 29.60 (2C), 29.62, 29.65, 29.66, 29.68, 29.69 (3C), 31.9, 52.1, 70.2, 71.8, 72.3, 77.1, 127.78, 127.82 (2C), 128.4 (2C), 138.0. IR ($CHCl_3$) ν: 3007, 2926, 2855, 2104, 1711, 1364 cm^{-1}. FAB-MS *m/z*: 454 ($M+Na^+$). HRMS *m/z*: 454.3415 (calcd for $C_{26}H_{45}N_3O_2Na$: 454.3409).

2-(Benzyloxy)-3-(hexadecyloxy)propanamine (6)

A catalytic amount of Pd–C was added to a solution of **20** (20.4 mg, 47.3 μmol) in methanol (1 mL), and the mixture was stirred for 1 h under hydrogen atmosphere. The mixture was filtered through Celite®, and the filtrate was concentrated under vacuum. The residue was purified using silica gel column chromatography (chloroform/methanol = 10/1) to afford **6** (18.9 mg, 98%). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.88 (t, J = 6.9 Hz, 3H), 1.25 (m, 28H), 1.52–1.59 (m, 2H), 2.78 (dd, J = 5.9, 13.3 Hz, 1H), 2.88 (dd, J = 3.6, 13.3 Hz), 3.41–3.56 (m, 5H), 4.59 (d, J = 11.7 Hz, 1H), 4.73 (d, J = 11.7 Hz, 1H), 7.26–7.36 (m, 5H). ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 14.1, 22.7, 26.1, 29.4, 29.5, 29.61, 29.62, 29.65, 29.68 (3C), 29.69 (3C), 31.9, 43.5, 71.4, 71.7, 72.1, 79.6, 127.6, 127.8 (2C), 128.4 (2C), 138.7. IR ($CHCl_3$) ν: 3385, 3003, 2928, 2855, 1585, 1454, 1352, 1113, 1070 cm^{-1}. EI-MS (20 eV) *m/z*: 405 (M^+). HRMS *m/z*: 405.3612 (calcd for $C_{26}H_{47}NO_2$: 405.3607).

2-[*N*-*tert*-Butoxycarbonyl-*N*-(2-benzyloxy-3-hexadecyloxy) propyl]aminoethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranosyl-(1→2)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (22)

Sodium cyanoborohydride (88.6 mg, 1.41 mmol) was added to a solution of **7** (1.70 g, 1.36 mmol) and **6** (672.3 mg, 1.66 mmol) in CH_2Cl_2 (70 mL), and the mixture was stirred for 4 h at room temperature. The reaction was quenched by pouring the mixture into a saturated aqueous sodium bicarbonate solution, which was then extracted with chloroform. The organic layer was washed with brine, dried over sodium sulfate, and evaporated. Boc_2O (1.56 ml, 6.79 mmol) and DMAP (a catalytic amount) were added to a solution of the residue in CH_2Cl_2 (50 mL), and the reaction mixture was stirred for 7 h at room temperature. The reaction was quenched by pouring the mixture into a saturated aqueous sodium bicarbonate solution, which was then extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 2/1) to afford **22** (1.29 g, 54%). The two diastereomers of **22** were separated by HPLC (*n*-hexane/ethyl acetate = 3/2).

22 (diastereomer A)

$[\alpha]_D$ = +4.2° (c = 1.20, $CHCl_3$). ^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.86 (t, J = 7.0 Hz, 3H), 1.24–1.64 (m, 37H), 1.86, 2.02, and 2.04 (each s, 3H, Ac), 3.22 (br t, J = 10.1 H, 1H, Man-6), 3.45–3.49 (m, 2H), 3.60–4.03 (m, 15H), 4.15–4.38 (m, 4H), 4.46 (dd, J = 2.0, 12.3 Hz, 1H, GlcN-6), 4.63–4.78 (m, 5H), 4.85–5.04 (m, 7H), 5.11 (m, 2H), 5.18–5.24 (m, 2H), 5.52 (s, 1H, PhCH<), 5.63 (dd, J = 9.3, 10.1 Hz, 1H, GlcN-4), 6.03 (m, 1H, GlcN-1), 6.47 (dd, J = 9.3, 10.8 Hz, 1H, GlcN-3), 7.17–7.22 (m, 1H), 7.27–7.44 (m, 22H), 7.51–7.59 (m, 9H), 7.92 (br, 2H). ^{13}C-NMR (100 MHz, C_5D_5N) δ: 14.3, 20.3, 20.5, 20.7, 22.9, 26.6, 28.4, 28.6, 29.6, 29.85, 29.93, 30.0, 30.2, 32.1, 48.4, 48.8, 50.0, 55.4 (GlcN-2), 62.5 (GlcN-6), 64.5 (Man-5), 67.3 (Glc-6), 68.1, 68.7 (Man-6), 69.8 (GlcN-4), 70.9, 71.0 (GlcN-3), 71.8 (GlcN-5), 72.4 (Glc-4), 72.5 (Man-3), 74.1, 74.4, 74.8 (Man-2), 75.7, 77.8 (Glc-5), 78.0, 78.8 (Man-4), 79.4, 82.7 (Glc-2), 85.1 (Glc-3), 96.7 (GlcN-1), 98.7 (Man-1), 102.1 (PhCH<), 104.2 (Glc-1), 123.99, 124.04, 126.9, 127.87, 127.91, 127.98, 128.03, 128.1, 128.2, 128.4, 128.5, 128.6, 128.69, 128.73, 128.8, 129.1, 132.2, 134.7, 136.0, 138.5, 139.0, 139.1, 139.4, 139.6, 139.9, 150.3, 155.7, 168.1,

169.2, 169.8, 170.4, 170.5. [§] IR ($CHCl_3$) ν: 3015, 2928, 2855, 1749, 1719, 1688, 1387, 1367, 1226, 1200, 1088 cm^{-1}. FAB-MS *m/z*: 1761 ($M + Na^+$). HRMS *m/z*: 1761.8595 (calcd for $C_{100}H_{126}N_2O_{24}Na$: 1761.8598).

22 (diastereomer B)

$[\alpha]_D = +18.8°$ ($c = 0.95$, $CHCl_3$). ^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.85 (t, $J = 7.0$ Hz, 3H), 1.24–1.61 (m, 37H), 1.85, 2.02, and 2.04 (each s, 3H, Ac), 3.23 (m, 1H, Man-6), 3.45–3.47 (m, 2H), 3.60–4.02 (m, 15H), 4.14–4.39 (m, 4H), 4.46 (dd, $J = 2.0$, 12.3 Hz, 1H, GlcN-6), 4.63–4.79 (m, 5H), 4.86–5.05 (m, 7H), 5.12 (br d, $J = 10.6$ Hz, 2H), 5.18–5.26 (m, 2H), 5.52 (s, 1H, PhCH<), 5.63 (t, $J = 9.7$ Hz, 1H, GlcN-4), 6.03 (br t, $J = 8.4$ Hz, 1H, GlcN-1), 6.47 (t, $J = 10.1$ Hz, 1H, GlcN-3), 7.20–7.22 (m, 1H), 7.27–7.44 (m, 22H), 7.52–7.60 (m, 9H), 7.93 (br, 2H). ^{13}C-NMR (100 MHz, C_5D_5N) δ: 14.3, 20.3, 20.5, 20.7, 22.9, 26.6, 28.4, 28.6, 29.6, 29.8, 29.9, 29.98, 30.01, 30.18, 32.1, 48.7, 48.8, 50.5, 55.4 (GlcN-2), 62.5 (GlcN-6), 64.5 (Man-5), 67.3 (Glc-6), 68.3, 68.7 (Man-6), 69.8 (GlcN-4), 70.9, 71.0 (GlcN-3), 71.8 (GlcN-5), 72.0, 72.4 (Glc-4), 72.5 (Man-3), 74.0, 74.3, 74.6, 74.8 (Man-2), 75.7, 75.9, 77.9 (Glc-5), 78.0, 78.8 (Man-4), 79.4, 82.6 (Glc-2), 85.1 (Glc-3), 96.7 (GlcN-1), 98.7 (Man-1), 102.1 (PhCH<), 104.1 (Glc-1), 124.0, 124.1, 126.9, 127.9, 127.98, 128.04, 128.1, 128.2, 128.4, 128.6, 128.69, 128.73, 128.8, 129.1, 132.2, 134.7, 136.0, 138.5, 138.8, 139.0, 139.1, 139.4, 139.7, 139.8, 150.3, 155.6, 169.9, 170.4, 170.5.[§] IR ($CHCl_3$) ν: 3026, 3017, 2928, 2855, 1751, 1719, 1686, 1387, 1367, 1236, 1200, 1088 cm^{-1}. FAB-MS *m/z*: 1761 ($M + Na^+$). HRMS *m/z*: 1761.8593 (calcd for $C_{100}H_{126}N_2O_{24}Na$: 1761.8598).

2-[*N*-*tert*-Butoxycarbonyl-*N*-(2-benzyloxy-3-hexadecyloxy) propyl]aminoethyl 3,4,6-tri-*O*-acetyl-2-acetamido-deoxy-2-β-D-glucopyranosyl-(1→2)-3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-benzyl-β-D-glucopyranoside (23)

Hydrazine hydrate (80% in water, 1.0 mL) was added to a solution of **22** (822.2 mg, 0.473 mmol) in ethanol (15 mL), and the mixture was stirred for 1.5 h at 80 °C. After cooling the reaction mixture to room temperature, the precipitate was filtered, and the filtrate was evaporated. Acetic anhydride (223 μL, 2.36 mmol) and DMAP (a catalytic amount) were added to a solution of the filtrate residue in pyridine (15 mL). The reaction mixture was stirred for 10 h poured into ice water and extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 1/1) to afford **23** (680.5 mg, 87%, 2 steps). ^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.85 (t, $J = 7.0$ Hz, 3H), 1.23–1.64 (m, 40H), 1.96 (s, 3H), 2.01 (s, 6H), 2.17 (s, 3H), 3.45–5.23 (m, 34H), 5.44–5.54 (m, 3H), 5.59 (s, 1H), 6.00 (br, 1H), 7.19–7.63 (m, 30H), 9.03–9.12 (m, 1H). ^{13}C-NMR (100 MHz, C_5D_5N) δ: 14.3, 20.55, 20.58, 20.64, 22.9, 23.4, 26.6, 28.4, 28.5, 29.6, 29.85, 29.92, 29.98, 30.00, 30.01, 30.2, 32.1, 48.7, 50.1, 55.6, 62.7, 65.1, 67.2, 68.1, 69.1, 69.8, 70.9, 71.8, 72.1, 72.3, 72.9, 74.5, 74.8, 75.0, 75.2, 75.7, 78.0, 78.7, 79.4, 82.7, 85.1, 99.5, 100.4, 102.1, 104.1, 123.0, 124.0, 126.9, 127.8, 127.9, 128.0, 128.1, 128.2, 128.35, 128.43, 128.6, 128.70, 128.73, 128.8, 129.1, 138.7, 139.1, 139.3, 139.5, 155.7, 169.9, 170.5, 170.6, 170.9.[§] IR ($CHCl_3$) ν: 3352, 3011, 2928, 2855, 1751, 1674, 1454, 1367, 1236, 1070, 1045 cm^{-1}. FAB-MS *m/z*: 1673 ($M + Na^+$). HRMS *m/z*: 1673.8655 (calcd for $C_{94}H_{126}N_2O_{23}Na$: 1673.8649). Anal. calcd for $C_{94}H_{126}N_2O_{23}$: C, 68.34; H, 7.69; N, 1.70; found: C, 68.12; H, 7.70; N, 1.43.

[§] The signals could not be assigned due to the presence of conformers at the appropriate temperature for measuring the ^{13}C-NMR spectra.

2-[*N*-*tert*-Butoxycarbonyl-*N*-(2-acetoxy-3-hexadecyloxy) propyl]aminoethyl 3,4,6-tri-*O*-acetyl-2-acetamido-deoxy-2-β-D-glucopyranosyl-(1→2)-3,4,6-*O*-acetyl-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-acetyl-β-D-glucopyranoside (24)

$Pd(OH)_2$–C (291.6 mg) was added to a solution of **23** (561.9 mg, 0.340 mmol) in methanol (15 mL), and the mixture was stirred for 15 h under hydrogen atmosphere. The reaction mixture was filtered through Celite®, and the filtrate was concentrated under vacuum. Acetic anhydride (321 μL, 3.40 mmol) and DMAP (a catalytic amount) were added to a solution of the residue in pyridine (15 mL), and the mixture was stirred for 4 h. Subsequently, a second quantity of acetic anhydride (321 μL, 3.40 mmol) was added to the reaction mixture, which was then stirred for another 5 h. The reaction was quenched by pouring the mixture into ice water, which was then extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (*n*-hexane/ethyl acetate = 1/4) to afford **24** (459.2 mg, 96%, two steps). ^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.85 (t, $J = 7.1$ Hz, 3H), 1.27–1.35 (m, 38H), 1.51–1.59 (m, 2H), 1.97 (s, 6H), 1.99, 2.00, 2.01, 2.06, 2.07, and 2.09 (each s, 3H), 2.10 (br, 9H), 3.46 (br, 2H), 3.66–4.07 (m, 8H), 4.24–4.27 (m, 2H), 4.34 (br, 1H), 4.48 (br, 2H), 4.58–4.62 (m, 1H), 4.75 (br, 1H), 4.90–4.99 (m, 2H), 5.24 (m, 1H), 5.38–5.74 (m, 7H), 5.87 (m, 1H), 6.03 (br, 1H), 9.20 (br, 1H). FAB-MS *m/z*: 1429 ($M + Na^+$). HRMS *m/z*: 1429.6724 (calcd for $C_{66}H_{106}N_2O_{30}Na$: 1429.6728).

2-[*N*-(2-Acetoxy-3-hexadecyloxy)propyl-15-(4-iodophenyl) pentadecanecarboxamido]ethyl 3,4,6-tri-*O*-acetyl-2-acetamido-deoxy-2-β-D-glucopyranosyl-(1→2)-3,4,6-*O*-acetyl-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-acetyl-β-D-glucopyranoside (25)

Methanesulfonic acid (one drop) was added to a solution of **24** (177.6 mg, 0.126 mmol) in CH_2Cl_2 (5 mL), and the mixture was stirred for 1 h at room temperature. Subsequently, a further two drops of methanesulfonic acid were added to the mixture, which was then stirred for another 2.5 h. The reaction mixture was poured into a saturated aqueous sodium bicarbonate solution, which was then extracted with chloroform. The organic layer was washed with brine, dried over sodium sulfate, and evaporated.

1-Ethyl-3-(3′-dimethylaminopropyl)carbodiimide·HCl (WSC; 38.8 mg, 0.202 mmol) and DMAP (a catalytic amount) were added to a solution of the residue (162.2 mg) and **3** (68.0 mg, 0.153 mmol) in CH_2Cl_2 (5 mL), and the mixture was stirred for 5 h. The reaction was quenched by pouring the reaction mixture into a saturated aqueous ammonium chloride solution, which was then extracted with ethyl acetate. The organic layer was washed with brine, dried over sodium sulfate, and evaporated. The residue was purified using silica gel column chromatography (chloroform/methanol = 40/1) and further refined by GPC to afford **25** (141.7 mg, 65%, 2 steps). ^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.86 (t, $J = 6.8$ Hz, 3H),

1.26–1.66 (m, 55H), 1.85 (br, 3H), 1.96 and 1.97 (each s, 1.5H), 2.00 (br, 6H), 2.07 and 2.08 (each s, 1.5H), 2.10 and 2.12 (each br, 6H), 2.13 and 2.16 (each br, 3H), 2.45–2.68 (m, 4H), 3.49 (m, 3H), 3.70–4.14 (m, 10H), 4.25–4.37 (m, 4H), 4.49 (m, 3H), 4.61 (dd, $J = 5.5$, 12.3 Hz, 1H), 4.76 and 4.79 (each br, 0.5H), 4.95 (d, $J = 8.1$ Hz, 1H), 5.25 and 5.29 (each s, 0.5H), 5.38–5.63 (m, 5H), 5.70–5.76 (m, 1H), 5.87 and 5.89 (each t, $J = 10.1$ Hz, 0.5H), 6.01 (t, $J = 10.1$ Hz, 0.5H), 6.03–6.08 (m, 0.5H), 6.98 (d, $J = 7.9$ Hz, 2H), 7.71 (d, $J = 7.9$ Hz, 2H), 9.17–9.25 (m, 1H). FAB-MS *m/z*: 1755 ($M + Na^+$). HRMS *m/z*: 1755.7621 (calcd for $C_{82}H_{129}IN_2O_{29}Na$: 1755.7623).

2-[*N*-(2-Acetoxy-3-hexadecyloxy)propyl-15-(4-tributylstannylphenyl)pentadecanecarboxamido]ethyl 3,4,6-tri-*O*-acetyl-2-acetamido-deoxy-2-β-D-glucopyranosyl-(1→2)-3,4,6-*O*-acetyl-α-D-mannopyranosyl-(1→6)-2,3,4-tri-*O*-acetyl-β-D-glucopyranoside (26)

Methanesulfonic acid (three drops) was added to a solution of **24** (166.6 mg, 0.118 mmol) in CH_2Cl_2 (5 mL), and the mixture was stirred for 3.5 h at room temperature. The reaction mixture was poured into a saturated aqueous sodium bicarbonate solution, which was then extracted with chloroform. The organic layer was washed with brine, dried over sodium sulfate, and evaporated. WSC (37.0 mg, 0.193 mmol) and DMAP (a catalytic amount) were added to a solution of the residue (152.3 mg) and **4** (86.7 mg, 0.143 mmol) in CH_2Cl_2 (5 mL), and the mixture was stirred for 5 h at room temperature. The reaction mixture was poured into a saturated aqueous ammonium chloride solution, which was then extracted with ethyl acetate. The organic layer was washed with brine, dried over magnesium sulfate, and evaporated. The residue was purified using silica gel column chromatography (chloroform/methanol = 40/1) and further refined by GPC to afford **26** (181.5 mg, 81%, two steps). The two diastereomers of **26** were separated by HPLC (using ethyl acetate).

26 (diastereomer A)

^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.87 (t, $J = 7.3$ Hz, 12H), 1.04–1.19 (m, 6H), 1.26–1.41 (m, 52H), 1.52–1.65 (m, 12H), 1.84 (br, 3H), 1.96 and 1.97 (each s, 1.5H), 1.99 (s, 1.5H), 2.01 (br, 4.5H), 2.07 (br, 3H), 2.10–2.13 (m, 12H), 2.16 (m, 6H), 2.56 (br t, $J = 7.5$ Hz, 1H), 2.62 (m, 3H), 3.50 (m, 3H), 3.71–4.14 (m, 10H), 4.25–4.37 (m, 4H), 4.50 (m, 3H), 4.61 (dd, $J = 5.5$, 12.6 Hz, 1H), 4.76 and 4.79 (each br, 0.5H), 4.99 (br, 1H), 5.25 and 5.30 (each s, 0.5H), 5.41–5.50 (m, 4H), 5.58–5.63 (m, 1H), 5.70–5.76 (m, 1H), 5.85–5.92 (m, 1H), 5.99–6.08 (m, 1H), 7.38 (d, $J = 7.7$ Hz, 2H), 7.64 (d, $J = 7.7$ Hz, 2H), 9.19 (br d, $J = 7.7$ Hz, 0.5H), 9.25 (br d, $J = 7.9$ Hz, 0.5H). FAB-MS *m/z*: 1919 ($M + Na^+$). HRMS *m/z*: 1919.9722 (calcd for $C_{94}H_{156}N_2O_{29}SnNa$: 1919.9713).

26 (diastereomer B)

^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.88 (t, $J = 7.3$ Hz, 12H), 1.04–1.21 (m, 6H), 1.25–1.43 (m, 52H), 1.54–1.70 (m, 12H), 1.85 (br, 2H), 1.96, 1.99, and 1.97 (each s, 1.5H), 2.00 (s, 3H), 2.01, 2.06, and 2.07 (each s, 1.5H), 2.09–2.12 (m, 12H), 2.125, 2.132, 2.15, and 2.16 (each s, 1.5H), 2.54–2.68 (m, 4H), 3.44–3.54 (m, 3H), 3.68–4.15 (m, 10H), 4.24–4.37 (m, 4H), 4.46–4.55 (m, 3H), 4.61 (dd, $J = 5.5$, 12.3 Hz, 1H), 4.76 and 4.79 (each dd, $J = 1.6$, 3.5 Hz, 0.5H), 4.93 (d, $J = 8.1$ Hz, 1H), 5.24 and 5.28 (each d, $J = 1.6$ Hz, 0.5H), 5.38–5.62 (m, 5H), 5.69–5.75 (m, 1H), 5.86 and 5.88 (each t, $J = 10.3$ Hz, 0.5H), 6.01 and 6.03 (each t, $J = 9.3$ Hz, 0.5H), 7.37 (d, $J = 7.5$ Hz, 2H), 7.63 (d, $J = 7.5$ Hz, 2H), 9.18 (d, $J = 8.4$ Hz, 0.5H), 9.19 (d, $J = 8.2$ Hz, 0.5H). FAB-MS *m/z*: 1919 ($M + Na^+$). HRMS *m/z*: 1919.9723 (calcd for $C_{94}H_{156}N_2O_{29}SnNa$: 1919.9713).

2-[*N*-(2-Hydroxy-3-hexadecyloxy)propyl-15-(4-iodophenyl) pentadecanecarboxamido]ethyl 2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→2)-α-D-mannopyranosyl-(1→6)-β-D-glucopyranoside (2)

Sodium methoxide (28% in methanol, 49 μL, 246 μmol) was added to a solution of **25** (141.1 mg, 81.6 μmol) in methanol (5 mL), and the mixture was stirred for 30 min at room temperature. The reaction mixture was neutralized with Dowex 50 (H^+) and filtered. The filtrate was concentrated under vacuum, and the residue was purified using silica gel column chromatography (chloroform/methanol/water = 8/2/0.1) to afford **2** (88.1 mg, 82%). The two diastereomers of **2** were separated by HPLC (using methanol).

2 (diastereomer A)

^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.85 (t, $J = 7.0$ Hz, 3H), 1.24–1.33 (m, 46H), 1.52–1.65 (m, 4H), 1.75–1.85 (m, 2H), 2.19 (s, 1.2H), 2.20 (s, 1.8H), 2.47 (br t, $J = 6.4$ Hz, 2H), 2.54–2.64 (m, 1.2H), 2.71–2.76 (m, 0.8H), 3.46–3.49 (m, 3H), 3.59–3.70 (m, 3H), 3.76–4.64 (m, 22H), 4.86 (d, $J = 7.9$ Hz, 1H), 5.22 (m, 1H), 5.28 (br d, $J = 7.5$ Hz, 1H), 5.54 (br s, 1H), 5.64 (br,, 10H), 6.98 (d, $J = 8.2$ Hz, 2H), 7.71 (d, $J = 8.2$ Hz, 2H), 8.94 (br, 1H). FAB-MS *m/z*: 1335 ($M + Na^+$). HRMS *m/z*: 1335.6562 (calcd for $C_{62}H_{109}IN_2O_{19}Na$: 1335.6567).

2 (diastereomer B)

^{1}H-NMR (400 MHz, C_5D_5N) δ: 0.85 (t, $J = 7.1$ Hz, 3H), 1.23–1.33 (m, 46H), 1.52–1.63 (m, 4H), 1.75–1.85 (m, 2H), 2.19 (s, 1.2H), 2.20 (s, 1.8H), 2.47 (br t, $J = 7.1$ Hz, 2H), 2.57 (quint, $J = 7.7$ Hz, 1.2H), 2.75 (quint, $J = 7.7$ Hz, 0.8H), 3.46–3.51 (m, 3H), 3.59–4.64 (m, 25H), 4.79 (d, $J = 7.9$ Hz, 0.6H), 4.83 (d, $J = 7.9$ Hz, 0.4H), 5.21 (br, 12H), 5.54 (d, $J = 1.5$ Hz, 0.6H), 5.55 (d, $J = 1.5$ Hz, 0.4H), 6.98 (d, $J = 8.2$ Hz, 2H), 7.71 (d, $J = 8.2$ Hz, 2H), 8.91 (m, 1H). FAB-MS *m/z*: 1335 ($M + Na^+$). HRMS *m/z*: 1335.6561 (calcd for $C_{62}H_{109}IN_2O_{19}Na$: 1335.6567).

2-[*N*-(2-Hydroxy-3-hexadecyloxy)propyl-15-(4-[^{125}I] iodophenyl)pentadecanecarboxamido]ethyl 2-acetamido-2-deoxy-β-D-glucopyranosyl-(1→2)-α-D-mannopyranosyl-(1→6)-β-D-glucopyranoside ([^{125}I]2)

Hydrogen peroxide (5% in water, 10 μL), 0.1 M hydrochloric acid (10 μL), and [^{125}I]NaI (5 μL, 13.4 MBq) were added to a solution of tributyltin derivative **26** (100 μg) in acetonitrile (20 μL). After stirring the reaction mixture at room temperature for 1 h, the mixture was added to a saturated aqueous sodium thiosulfate solution, which was then extracted with ethyl acetate and concentrated under vacuum. The residue was treated with methanol (20 μL) and sodium methoxide (28% in methanol, 3 μL) for 30 min, and then the mixture was neutralized with 1 M hydrochloric acid. The residue was purified using HPLC on a Cosmosil 5C_{18} AR-300 column (4.6 mm × 150 mm, Nacalai Tesque, Kyoto, Japan) using methanol/water (98/2, v/v) as the mobile phase at a flow rate of 1.0 mL/min. [^{125}I]**2** (6.6 MBq) was isolated, and it was identified by co-injection HPLC analysis with **2**. The radiochemical yield was 49%, and the radiochemical purity was 95%.

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Conflict of Interest

The authors did not report any conflict of interest.

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